Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-605-RC4, 2021

Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Projected changes in Rhine River flood seasonality under global warming" *by* Erwin Rottler et al.

Anonymous Referee #4

Received and published: 4 January 2021

General

The paper addresses a highly relevant subject on changes in flood seasonality in the Rhine basin, by analysing how climate change affects different components of the water balance and their aggregated effect on peak flows. The authors elegantly demonstrate by means of model simulations for different GCMs and climate scenarios the contributions of snow melt and rainfall-driven runoff to peak flow generation over the seasons. These analyses form a relevant contribution to earlier studies on the impacts of climate change on peak flows in the Rhine basin, provide nice insight in the underlying contributions of rainfall and snowmelt, and indicate their effects on time shifts in peak flow occurrences. The paper's title well covers the contents; the paper is well-structured, clearly presents its results in text and figures, and the interpretations, dis-

cussion and conclusions are well supported by the results. I would rate the significance and quality of the paper 'Good'.

Specific comments:

Fig 1: I would suppose that the nival peak not only shifts to earlier in the season but also becomes smaller under CC - as there will be less total snow accumulation over the winter season.

Line 30: 1.5, 2 and 3 degrees warming - relative to 1970 - 2000

Section 2: provide a bit more information on: which parameters did you calibrate? In particular you have a detailed representation of crops and soil types, did you use reference values in all cases, or did you do any calibration here? How did you choose LAI values for different vegetation types and seasons and latitude? How did you perform the bias correction to GCMs for future climates?

P4, L11: assess -> assesses

P4, L13: bases -> is based

P6, L6-9. Do I understand here that the projection times of the periods where the 'targeted' warming was reached was different for each realisation? And with different RCPs you may reach the same warming at different moments (e.g. 1.5 degree under RCP 8.0 early in the century, and RCP2.6 only late) - but to what extent are these scenarios different in your simulations (associated P?). Can you indicate which are the according time horizons used in your simulations?

P6, L14: for the Rhine basin as a whole (e.g. Cologne) a 5 day-period for the precipitation sum seems quite short to generate extreme floods, in particular in view of saturating the soil and travel time of peaks from tributaries.

P6, L19: river discharge at Basel is considerably dampened by the effects of the Swiss lakes. For that reason, earlier studies focused on catchments upstream of the lakes (e.g. Murg, Thur). Can you indicate to what extent timing and maxima of small peaks - in particular after a dry period with low lake levels - are affected by this?

Figure 5: Please indicate on how many runs each histogram is based. From the methods I read how many GCMs reached each warming, with only 8 of them reaching 3 degrees, but this is not clear for the other histograms. To what extent do different numbers of realisation result in different occurrences of highest extremes, and did different GCMs result in different extremes under - in spite of bias correction?

Fig 5; P8, L9: whereas both for Basel and Cochem there is a decline in the timing of summer maxima for higher temperatures, Cologne shows a small peak emerging around DOY 250 - can you explain this? Consider using the same horizontal scale for figs 5d-f.

P10, L4: is detected -> are detected

P10, fig 6 (k,l): by displaying annual maxima distributions we indeed can see how these shift over time, but we cannot see how shifts evapotranspiration maxima link to peak flows, as the connection to the flood events is lost: we cannot see how much was the 'reduction' of the annual peak flow maxima due to evapotranspiration loss (as you do in fig 6 ab indicating the 'contribution' of snowmelt to the annual maxima). It makes sense that under a warming climate annual maximum evapotranspiration goes up - but if that happens in summer when floods never arise it is hard to judge the role of evapotranspiration in changing peak flows. In fig 9g we can see that the contribution of evapotranspiration change is small indeed.

P11: Discussions -> discussion

P11, L4: ....diminish seasonal snow covers -> please add in a few words the key aspects of that: the total volume, the duration and the timing of melt.

P11, L6: Smax14 is singular.

P11, L8: 'forward' -> in first time use, explicitly explain that you mean: 'earlier in the

year'

P11, L10, 13-14: two factors may play a role: the timing of melting, and the amount of snow that has accumulated so far to be available for melting - you do not indicate the maximum amount of snow that has accumulated by the end of the season to be available for melt.

P11, L15. I do not see a contradiction suggested by using 'however'. Actually, you change subject here to low flow situations, as caused by disappearing glaciers and intensified evapotranspiration, which becomes different from 'lower maxima',

P12. l6 (and in the rest of the paper, in particular in the conclusion, P14, L32): I am not sure whether you should formulate this as 'intense rainfall events' in mm per hour and use this formulation for both summer and winter. 'High intensity' rather relates to high intensity summer storms - as you indicate in lines 12-15 here, but for the winter season I would not formulate that as intensity. Moreover, you consider in your study accumulated precipitation sums over 5 days - that is an amount, not an intensity.

P12, L12. Here you make a relevant statement - that the summer extremes were still supported by snow melt from the Alps to produce their maxima - I presume that that has been derived from the associated historic descriptions. With reduced snow melt in late spring this would indeed reduce the risk of summer floods. Conversely, higher temperatures under future climate change may lead to more intense summer precipitation - still causing higher peak flows. Here we may encounter the questions: does the latter only hold for smaller catchments within the basin, or do these still feed large floods to Cologne? And some GCMs show a N-S difference in precipitation change (some even the signal) across the Rhine basin: is that the case in your experiments? From the histograms in fig 6g this is hard to derive. It would affect probabilities of extreme summer floods, as we experienced in early 2000s in the Elbe.

P14, L3: It is not a true 'interaction' between snow fall and precipitation, but their effects are counterbalancing - as you explain in the following lines.

P14, L9: hint -> suggest

P14, L14: originate - > originates; During this period, we have experienced already over 0.5 degree of warming, so it would be interesting to know what the average for the past few decades would be.

P14, L33: 'intense precipitation events' (see earlier comment): would you describe the precipitation driving the Elbe floods earlier this millennium as 'high-intensity' or 'large amounts'? (actually, I think it was a combination of both....). I would avoid suggesting that more intense summer showers will cause the Rhine to flood Cologne.

Discussion point to consider: Your 30-year time slices from which you determined the flood maxima may not include the very extremes that are relevant for flood protection - in the box plot you see a few isolated extremes that occurred in your simulations. To what extent do you think this affects your overall message?

P15, L10. Under recommendations: Would calibration on observed extent of snow cover using RS support calibration of snow melt modules to support these analyses? To what extent would precipitation falling on a snow cover further enhance melting of a snow cover (so: not snow melt not only depends on T, but also on warm precipitation water) - and would we need to consider that in modeling? Lakes: of course these buffer flow in dry periods, but that was not the focus of your paper, it might be interesting to see their role in generating peak flows.

For policy makers / river managers it may be relevant to see a conclusion on whether we should anticipate changes in summer floods - as the use of the river banks (agriculture, tourism) has a strong seasonality.

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